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OF DEATH STARS AND DEATH RAYS:

A GLIMPSE AT THE FUTURE OF SPACE WARFARE

by

Major David A. Friedman, USAF

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Advisor:

Lt Col Thomas I. Savoie

Maxwell Air Force Base, Alabama

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Disclaimer

Abstract

Since its first big splash in Operation DESERT STORM, space has experienced a revolution in warfare the likes of which have often been compared to that of Airpower following World War I. But for all the promise of an expanded space force following the release of the 2001 Space Commission Report, the events of 9/11 forced the United States to turn its attention to irregular warfare. Now with the conflicts in Iraq and Afghanistan coming to an end and with the pivot in motion to confront threats in East Asia, the United States is returning to conventional warfare to face the challenges that lie ahead. Yet, questions of how space will play a role in this and other future fights have largely gone unanswered.

This essay attempts to build an understanding of where space warfare is heading over the next thirty years and suggest what, if anything, the United States can do to maintain its asymmetric advantage in this domain. In looking at the diplomatic landscape and at the credible threats coming from China, Russia, and even Japan, a narrowing capabilities gap is approaching between the United States and its competitors. Although space control technology and satellite designs will evolve, political constraints and the ambiguity inherent with space warfare will limit conflict to the tactical and operational levels of war, ultimately yielding a relative stalemate in this domain. Parity will ensue until a game-changing technology fundamentally alters this landscape providing space with a lasting and enduring purpose. This paper offers two potential space-based energy sources that may spark this revolution, resulting in sovereign state boundaries extending their reach into lunar and near-Earth space territory. While little has been offered to address how warfighting theory would be modified in this expanded construct, what does exist may serve as a suitable starting point.

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Since its first big splash in Operation DESERT STORM, space has experienced a revolution in warfare the likes of which have often been compared to that of Airpower following World War I. For all the promise expected after the 2001 Space Commission Report decreed that "U.S. national security space interests be recognized as a top national security priority,"[1] the revolution, as it were, stagnated following the attacks of 9/11 when the U.S. immersed itself in irregular warfare. While statistics show that space systems were far more integrated into mainstream warfare during Operations Enduring and Iraqi Freedom, (60 percent of munitions were precision guided compared to just nine percent in Operation Desert Storm[2]), the buzz these days has shifted towards cyber-warfare, a national security strategy refocused on East Asian policy, and a military drawdown consistent with a nation recovering from extended fighting in Iraq and Afghanistan. Yet on the periphery, China continues to explore anti-satellite technology, North Korea appears to be mastering the intercontinental ballistic missile, and Japan has become a leader in commercial and scientific space technology. Presuming what we are witnessing is a lull and not a crescendo, this essay attempts to project where space warfare is heading over the next thirty years and to suggest what, if anything, the U.S. can do to maintain its asymmetric advantage in space. To better understand this question, the paper will investigate the diplomatic constraints and military threats the U.S. could face over the next several decades with respect to space. With this knowledge in hand, this paper will then explore how space warfare strategies may evolve and how advances in technology will bolster these strategies. Finally, in a bold attempt to look beyond the horizon, this paper will offer a glimpse of how a single revolutionary leap in technology could forever change the energy industry and completely alter the framework of joint warfare.

INTERNATIONAL DIPLOMACY

To say that the U.S. has enjoyed a tremendous economic and military advantage through its use of space over the past 20 years would be an understatement. Space-based communication is essential to linking geographically separated forces; the ubiquitous Global Positioning System (GPS) with its timing and navigation payloads has just as much impact on synchronizing mobile phone systems as it does aiding in the delivery of precision munitions; and space-based reconnaissance has given the U.S. a tremendous information advantage over its rivals since the launch of Corona in 1960.[3] Yet for all the investment in military space, the U.S. has relatively little infrastructure in place to defend its space systems from attack.

Absent a robust military defense, the U.S. has relied upon diplomacy as its primary method for maintaining peace in space through the Outer Space Treaty (OST) of 1967. A product of the Cold War, the OST was critical in curbing a U.S.-Soviet nuclear arms race into outer space.[4] Some key principles of the treaty are:[5]

• States shall not place nuclear weapons or other weapons of mass destruction in orbit or on celestial bodies
• Outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means
• The Moon shall be used exclusively for peaceful purposes
• States shall be responsible for national space activities whether carried out by governmental or non-governmental entities
• States shall avoid harmful contamination of space and celestial bodies

In addition to providing clear language in preventing a nuclear escalation, the OST also had the foresight to address commercialization and space debris. Although matters of sovereignty seem to have little relevance today, they could become a greater issue if key orbits become contested or if the moon becomes colonized.

One noted gap in the OST is on the matter of space warfare. While the OST has successfully prevented an escalation in nuclear warfare, its applicability comes into question

when addressing how laws of armed conflict would govern military activities in space. One school of thought, represented by James Clay Moltz, believes that space should be used for the benefit of mankind and be kept weapons free, in the spirit of the OST.[6] A more realist school of thought, represented by Everett Dolman, suggests that the weaponization of space is inevitable and, thus, the U.S. should lead the charge as they are best suited to maintain judicious control of space.[7] Nations that do not consider the OST to provide enough security can take solace that they may withdraw from the treaty given one year notice.[8] In looking forward to mid-century, it is unclear if the OST will continue to serve the international community's needs or if will become another relic of the Cold War. A major conflict extending into space may be the catalyst that forces a revision to these internationally accepted norms.

THE THREATS

With the launch and successful destruction of a weather satellite in 2007, China shocked the world with its demonstration of anti-satellite (ASAT) technology.[9] While not the first use of the technology (the U.S. and Soviet Union successfully tested ASAT technology 20 times between 1968 and 1982[10]), it did force the world to take notice and reconsider their previously held assumptions about the relative safety of their space systems. When considering these and other threats to U.S. dominance in space over the next thirty years, it is crucial to understand what game-changers are on the horizon. Looking at near-peer competitors, emerging space powers, and regional rivalries will help conceptualize the threats that the U.S. should consider defending against.

When it comes to near-peer competitors, China is one to look out for. Their space capability is evolving at an extremely rapid pace and is by far the most advanced in Asia.[11]

Much of their efforts over the past decade have been focused on catching up to the U.S. by acquiring or developing traditional space applications. This can be seen through a parallel development of their missile and space launch vehicle programs.[12] They have acquired an extensive space-based optical and radar reconnaissance system while maintaining the top terrestrial-based electronic intelligence system in Asia.[13] Chinese counterspace technology appears to be on the rise as well as they look to mature their direct-assent ASAT capability,[14] while pursuing more exotic hunter/killer and parasitic satellite capability.[15] Some reasonably see this as a deterrence effort to counter U.S. posturing in the Pacific,[16] but whatever efforts they put in now could be the basis for their future capability.

Looking forward, the Chinese have the plans in place that could further extend their momentum into space. They are performing extensive research in microsatellites technology that could potentially exceed U.S. capability.[17] Microsatellite technology could be leveraged in creating dispersed satellite constellations, making their existing capability more inherently robust. Their manned spaceflight and lunar programs have serious ambition as well. China has already performed successful space walks and is looking to independently develop three small space laboratories and a 30-ton space station by 2022.[18] They also are planning to send a spacecraft to the moon by 2017, with a follow-on manned mission by 2024.[19] While skepticism about the timelines may be warranted, their focus on the moon should not be taken lightly. Considering their national strategy has been focused on catching up to the U.S., their associated space strategy remains in step. The potential for long-term energy mining from the moon (discussed later in this paper) must also be a consideration as there will be a fierce competition to be the first to proliferate lunar natural resources.

There is no doubt that China is behaving as a near-peer competitor. While many observers are concerned that Chinese growth is unsustainable, the depth with which China builds its capability now will have long-lasting impacts to their space-related ambitions in the decades to come.

Another nation that poses a significant threat to U.S. space dominance is Russia. As a space power during the Cold War, the Soviet Union employed a similar range of capabilities to that of the U.S. and was renowned for its economical and robust designs.[20] To this day, they are highly regarded in their ability to manufacture rocket engines. Even the U.S.'s Atlas V rocket leverages the Russian RD-180 engine.[21] Yet, Russia has seen tough times following the fall of the Soviet Union. By 2001, 68 out of 90 of their operational satellites were approaching or had exceeded service life standards.[22] However, in 2005, they unveiled a 25 year space strategy covering 2015-2040.[23] In addition to revitalizing their manned space program and supporting infrastructure, they have also set their sights on completing a moon mission by 2025 and establishing a moon base by 2032.[24] As for weaponizing space, Defense Minister Sergei Ivanov has gone on record as saying "We are categorically against militarizing outer space."[25] Perhaps, this sentiment has more to do with Russian diplomacy and a space budget that is 1/16 of the United States[26] than it does with a firm belief in retaining space for peaceful purposes. A cash-strapped Russia that still retains a mastery of rocketry and space-based reconnaissance must be considered a viable threat for to U.S. space superiority over the next thirty years.

While assessing Chinese and Russian space capabilities seems prudent based on their current or previous performance, one must also consider those nations that may emerge to a role of prominence based on their potential. Japan, known for its innovations in space application

technology, along with boasting the world's third largest economy at 6.6 trillion dollars,[27] could potentially rise and assume the role of a military space power.

In the past, much of what has tempered Japanese development of its military space capability, if not their overall military force, is their pacifist legacy following World War II. In 1969, the Japanese Diet went so far as to explicitly state that "objects launched into space…shall be limited to peaceful purposes."[28] Over time, due to increased security threats within the Pacific Rim, such as North Korea's aggressive development of the Taepo-Dong missile and cool relations with China, this standard has become increasingly more flexible.[29] In 1998, following a North Korean missile test that launched directly over Japan, the Japanese Self-Defense Force began development of its first satellite reconnaissance system.[30] By 2003, Japan had successfully launched an electro-optical imaging and a synthetic aperture radar satellite, each with approximately one meter resolution.[31] In 2008, the Japanese Diet went so far as to sanction expanded military activity in space, provided that offensive weapons were not developed.[32] Despite these modest advances, Japan still only devotes 0.25 percent of their budget towards space applications, far behind that of the U.S. or China.[33] Moreover, they remain heavily reliant on the U.S. for their intelligence collection needs.[34] Japan's self-imposed policy toward pacifism has in large part limited their ability to function as a military power, today.

Yet, one cannot ignore what Japan has managed to accomplish in the space arena in terms of peaceful applications. For starters, Japan has a very mature rocket program, with many successful launches since World War II.[35] Japan also has sound technical ability in spaceflight, satellites, and robotics.[36] For instance, in 2003, they delivered a spacecraft to the Itokawa asteroid, collected soil samples, and safely returned the mission to Earth.[37] In 2007, they demonstrated their mastery of rendezvous and imaging technology by successfully mapping the

lunar surface.[38] These skills may directly benefit Japan when applied towards space control technology or lunar missions.

Looking forward, Japan's path should parallel that of China or Russia, as they will continue to balance security, diplomacy, and national achievement priorities. Near term, they will look to expand their military space capability by adding a Northeast Asia-centric GPS system, enhancing their space-based communication backbone in supporting naval and army forces, and even partnering with the U.S. in the area of missile defense.[39] In the 2020s, they too have their eyes set on a lunar mission, first with robots followed by a manned mission.[40] Much remains to be seen as to how the Japanese will in fact develop their military. Diplomatic relations with North Korea, China, and even the U.S. will undoubtedly play a role. If Japan's population should continue to decline[41], this too may impart some unforeseen, deleterious effects. It is not unfathomable to consider Japan as a principle space power with in thirty years. This could bring three or four space powers to the front, all capable of vying for space superiority without any one nation achieving a significant quantitative or qualitative advantage.

While several other regional powers could be analyzed as a potential space threat, the names are not nearly as important as the style of warfare they may bring to the fight. The ever-present tension between India-Pakistan highlights one example of how maintaining space superiority in 2040 will be an increasingly complex challenge. While both nations possess nuclear weapons, both are now focusing their attention increasing their space capability. Since 2007, India has increased their national space budget by 35 percent placing considerable focus on reconnaissance, early warning radar, and possibly even active satellite defense technology.[42] Pakistan, on the other hand, has huge ambition, but lacks the current wherewithal due to financial and technological limitations.[43] Given its current relationships with China and North Korea, it is

certainly feasible that Pakistan could receive assistance in developing ASAT technology.[44] With both sides turning their attention to expanding their space capability, it is certainly possible that saber rattling, previously seen through threats of a nuclear volley, may now transition into space. If such posturing does occurs in the next thirty years, this regional conflict, as Moltz suggests, may quickly spillover into a global affair impacting all spacefaring nations.[45]

STRATEGY AND TECHNOLOGY

The point of this analysis has not been about predicting whether China or Russia will most likely represent the greatest threat to the U.S.; whether Japan will be the new kid on the block; or which tertiary actor may prove to be a greater nemesis. Over the next thirty years, these nations will all experience periods of economic turbulence and other domestic challenges that will take their focus away from international security, and by extension, space security. The U.S. in this regard would be no different. Rather, the key to this analysis has been to create an understanding, through extrapolation, of how the space landscape might appear in the future and through this understanding, project how a space-power might evolve its capability and capacity to counter emerging and credible threats.

Based on the brief analysis above, it is a near certainty that space-faring nations will multiply; this is to say rather than simply conceding U.S. space dominance, other nations will choose (and have begun) to develop their own space-based communication, navigation and remote sensing capabilities, the principle enablers to terrestrial warfighting. These nations will also develop counterspace technologies which will defend their vital space assets and attempt to deny the same to their adversaries. Interestingly enough, a majority of potential space powers are already nuclear powers.

At the strategic level of space warfare, nuclear weapons do not project to be a viable military weapon. Similar to terrestrial warfare, the political capital required for their use will simply not justify a military advantage gained from their employment. If a nation chose to use nuclear weapons, the biggest impact would be seen from the electromagnetic pulse (EMP) delivered to un-hardened spacecraft. However, since only the most strategically significant satellites would be hardened due to the inordinate expense created through their added weight and associated launch costs, an EMP weapon would disable both friendly and enemy spacecraft alike within the weapon's field-of-view, leaving its use for only the direst of circumstances. A similar rationale could be applied to the less invasive, yet politically sensitive kinetic ASAT weapon. By 2040, the kinetic ASAT capabilities already seen from Russia, China, and the U.S. will become more refined, extending their reach to higher orbits, such as geosynchronous orbit where communications satellites are primarily located. Yet these weapons and any associated space-based missile defense systems, once fielded, will serve primarily as deterrents, rather than as conventional capability.

This leaves the operational and tactical levels of war where counterspace warfare will be conducted alongside terrestrial operations to achieve synergistic effects in an expanded global battlefield. When considering counterspace warfare, one must understand that it is inherently ambiguous. Military effects achieved in space will either be temporary or conducted in such a manner where attribution is extremely difficult to affix. Many promising operational concepts identified in open-source embody this notion of ambiguity. Some involve temporarily blinding or dazzling satellite sensors using lasers or paint-like substances.[46] Others utilize electromagnetic transmissions, which could jam satellite uplink signals or signal collectors.[47] Some even suggest that satellites could even be "hijacked" through a cyber-attack if the satellite command and

control system could be decrypted and decoded.[48] This class of denial or disruption weapon will be secretly developed and covertly employed concurrently or as a precursor to a terrestrial engagement. Yet, as these weapons are tested and employed, their use will reveal key aspects of the technology that will allow competing nations to catch up. Although a long-term asymmetric advantage is unlikely to be achieved from such a weapon, the short-term potential for creating a pivotal advantage is real.

Based on these threats, space-powers will look to devise a counterstrategy to preserve their capability. Because of the ambiguity involved in this style of warfare and the clandestine nature of the threat, it will initially be difficult to detect at what decisive point an enemy may choose to strike. Yet, one vulnerability that stands out among others relates to existing satellite architectures, which currently tend to be built around large, expensive, multi-mission constellations that possess little, if any, mission redundancy. Thus, a natural progression in space warfare will be to eliminate these vulnerabilities by building more distributed architectures. Consider two current distributed platforms employed today: GPS and the Iridium satellite phone network (each with approximately 30 and 66 satellites in each respective constellation). In addition to global coverage, a key benefit of such a setup is that the loss of a single satellite only degrades the system marginally while preserving the overall mission. In the case of GPS, its constellation design forces U.S. adversaries to search for other vulnerabilities that may be well defended, such as a command and control node, or which would only achieve a localized effect, like GPS jamming. Although simple in design, these platforms can be the basis for a new satellite constellation strategy.

Combining distributed architectures concepts with emerging technology trends could yield new ways to support the full range of space-based utilities. It is important to remember that

the biggest strike against a trend towards distributed architectures has been, and will continue to be, related to launch costs, which are directly tied to the weight of the satellite. With this in mind, consider two technologies that may serve as a workaround until a time when space launch costs become more affordable: the Buckytube and piezoelectric materials. Buckytubes are long thin hollow tubes made up of precisely-aligned carbon atoms possessing a theoretical strength 600 times greater than steel.[49] Replacing a satellite's structure with these Buckytubes would reduce a spacecraft's weight by a factor of 100.[50] While material science still has much work to do to mature this technology, the potential benefits seen by constructing lighter, more durable satellites at a fraction of today's launch costs presents a unique opportunity to shift risk away from overly-expensive, multi-mission design strategies.

Similarly, piezoelectric materials hold the key to reducing weight on spacecraft that use optical or antenna elements. Historically, the trusses and mirrors that support these mission sets are constructed on Earth and are a principle contributor to a satellite's overall weight. As an alternative, satellites of the future could deploy and shape mirrors and reflector elements through the use of these piezoelectric materials. When combined with an active control system and an electron beam, a curvature in the piezoelectric material is induced to support specific mission needs.[51] With these reduced weights, launching multiple satellites at a time becomes more plausible. These satellites could then operate in a coordinated manner to produce extremely large apertures, for transmission or reception, ranging from 300 meters to 300 kilometers, a significant improvement compared to today's performance.[52]

Time will tell whether these or other technologies will mature to the point that they can be operationalized in the next thirty years. The acquisition and employment of such concepts will be dependent on the perceived threat, not to mention the economic viability of the material

themselves. Likewise, one can only assume that a distributed architecture counterstrategy will in-turn be countered. What you will have in this interim period, where space's sole function is to provide effects to terrestrial warfighters, is a cat-and-mouse game that can be equated to *trench warfare in space*. That is until space yields a greater economic purpose.

WHAT'S NEXT FOR SPACE AND WHAT IT COULD MEAN MILITARILY?

With all due to respect to the space tourism industry, finding a lasting and enduring purpose for space is more likely to be driven by mankind's ever-increasing consumption of energy and natural resources than to fulfill a need to explore the universe. To that end, consider the possibilities in looking to space for space-based solar power collection and to the moon for its natural resources.

The concept behind space-based solar power (SBSP) is remarkably simple. Given the ample amounts of energy that the sun continuously emits (for example, an object in geosynchronous orbit would see 1366 watts/meter^2), one need only place a series of solar collectors in a continuously lit orbit, and then convert that energy into radio-frequency energy that could be safely transmitted to a receiver on the ground.[53] As an illustration, consider a space-based solar farm of collectors placed in geosynchronous orbit in a band one kilometer wide encircling the Earth. The theoretical output of such an entity could produce 212 terawatt-years of electricity, compared to the roughly 250 terawatt-years contained in all of the Earth's oil reserves.[54] The power collected could be transmitted to Earth and inserted directly into a national electrical grid, to a developing nation that lacked a means to easy access, or even to deployed forces, who traditionally would rely on long logistical trains for support.[55]

Beyond the enormity of a project covering such a large swath of space, there are clearly some technical limitations to such a concept. Even with some of the boldest projections for solar cell advancement, the maximum efficiency for such designs are capped at a projected 65 percent.[56] Current launch capability and costs provide an even greater impediment to successful employment of this concept. By today's lift standards, a single SBSP satellite producing 10 mega-watts of electricity is projected to weigh 3000 metric-tons.[57] Couple that with the United States' current lift capability of 120 metric-tons at roughly 15 times per year would require such a mission to launch 120 times by today's standards.[58] Further, such lift capability comes at a cost of $20,000 per kilogram of payload.[59] Such a plan would cost consumers $1-2 per kilowatt-hour[60], well above current standards of $0.05 per kilowatt-hour.[61] Clearly, a successful business model does not exist today for this technology. However, if advances in space launch technology were to come to fruition, say through magnetic levitation catapults or air-breathing engines employed during the initial phase of flight, launch costs could go down to an intriguing $200 per kilogram, order of magnitude less than today's standards.[62] When considering GPS as a case study in which a satellite technology initially required Department of Defense seed money and a specific military need to get started, we now a see technology that evolved into an enormous commercial industry. So too could be the formative path for SBSP.

The moon also presents a potential boon of natural resources worth extracting. Aluminum and titanium ores, pure iron, calcium and silicon all exist in large supplies[63] and could be used to support a lunar colony. More interestingly, the moon is projected to contain a staggering amount of Helium-3, a byproduct of the hydrogen isotope tritium's radioactive decay, which is ejected naturally from the sun and carried throughout the solar system via the solar

wind.[64] While the moon is estimated to contain one million tons of helium-3 in its upper crust, the Earth contains very little due to the protective sheath of its magnetic field.[65]

The potential benefits for Helium-3's use in nuclear fusion are remarkable. Helium-3 has an energy potential ten times greater than fossil fuels without generating radioactive waste or creating water or air pollution found in modern-day nuclear fission techniques.[66] Moreover, substituting helium-3 greatly reduces the complexity of fusion reactor containment designs, making nuclear fusion practical for the first time.[67] If the full potential of energy were realized, there would be enough energy to meet Earth's current power requirements for the next 10,000 years,[68] an eye-opening statistic that could benefit all of mankind.

Space powers have taken note. Based on China, Russia, Japan and the U.S.'s expressed interest in lunar exploration (highlighted earlier in this paper), economic and energy dominance must be a primary consideration for investing in these missions, even if such intentions are not declared publicly. Similarly, it has been argued that the first space race to the moon between the USSR and the U.S. was actually a backdrop for a covert space race of national capabilities.[69] Considering the remarks of Ouyang Ziyuan, chief scientist of China's lunar program, "Whoever first conquers the moon will benefit first,"[70] such benefits are clearly a consideration in the minds of the leaders who will be funding these efforts.

There are definitely significant hurdles to integrate helium-3 fusion into any nation's energy portfolio, both technically and politically. As helium-3 is dispersed across the lunar surface, large-scale mining operations and specialized equipment needed to extract the gas from lunar rocks will require significant infrastructure that will undoubtedly need to be shipped from Earth.[71] As highlighted above, launch costs would need to decrease in price. Additionally, with little helium-3 on Earth to experiment with, commercial-sized nuclear reactors that would

support helium-3 fusion could be at least fifty years away from reality.[72] Politically, establishing a permanent presence on the moon will raise intense questions of territorial sovereignty and who can profit from the Moon's natural resources that, to this point, have been only a theoretical discussion. To wit, only 13 nations have ratified the 1984 Moon Agreement, none of which were space-faring nations previously discussed.[73] Yet, given the astronomical costs anticipated with this endeavor, one must at least consider a strong preference from the international community to make lunar mining for Helium-3 a multi-national effort, similar to that of the International Space Station. Suffice it to say, any nation who chooses to seize the initiative to mine helium-3 will set the tone for such discussions.

It remains to be seen whether SBSP or helium-3 will generate a revolution in the energy markets over the next 30-50 years. Considering how the U.S. went to war with Iraq over oil in the 1990s, one can certainly assume that any nation with the means will go to great lengths to ensure its energy security. Depending on the crisis of the day, space powers may look to accelerate their research and development efforts in these or similar technologies. Yet, one thing remains certain: the day that a single nation begins to rely on space-based energy as a significant contributor towards its energy portfolio is the day that the space landscape will fundamentally change. New geography (or astrography and lunography, if you will), will be added to the world consciousness. Transfer orbits, linking the Earth, moon, and most prevalent orbits will be synonymous to trafficking routes of land, sea, and air. These will present new challenges for space-faring nations to defend along with opportunities to exploit. Thus, the interim limits of space warfare, mired in parity, will be overcome by the latest expansion to technology, and as such, the Earth-Moon system must now be considered when developing any future military strategy.

Outside of science fiction, little has been proposed that explores defense concepts in the expanded Earth-Moon system. What does exist may serve as a suitable starting point. Stine's Gravity Well Theory argues that the Earth-Moon system could be controlled from five libration points in space, places where gravity is nullified between the Earth, Moon and Sun.[74] These points serve as a theoretical high ground where anyone occupying these points has a gravitational advantage over an adversary occupying lower territory.[75] Everett Dolman builds on Gravity Well Theory by applying Mahan's naval war theory of sea routes and choke points to space orbits and gravity wells.[76] He postulates that a nation could gain space superiority, preventing other nations from launching and deploying assets, by placing space-based lasers or kinetic energy weapons at the top of the gravity well.[77]

Even U.S. military joint warfighting doctrine has the seeds to begin joint warfare in an Earth-Moon system. Both Joint and Army warfighting doctrine discuss how some military operations will be conducted in noncontiguous operating areas.[78] The Army further recognizes the need for higher-headquarters commanders to oversee both areas to ensure unity of command for the entire operation.[79] Interestingly enough, it notes that in restrictive terrain, "security forces [should] focus on key terrain such as potential choke points."[80] Given the technical challenges involved with launch, the Earth-Moon system would certainly meet the criteria of a restrictive environment. Beyond that, the theory and doctrine that would guide such operations remains unwritten, awaiting the next generation of warriors to tackle this wide-open problem.

CONCLUSIONS AND RECOMMENDATIONS

From a simple view of today's space environment, one can easily see a more contested, congested, and dangerous place to conduct operations. Nothing within the realms of technology

or international law suggests that this will change in the next 30 years. The U.S. should expect more competition from China, Russia, and Japan as they develop comparable communications, navigation, and reconnaissance capability. While there is a fair chance that one or more of these nations may operationalize strategic counterspace technology, such as an EMP device or a kinetic ASAT weapon, these technologies will act as deterrents, much like nuclear weapons on Earth, but will not fundamentally alter the conduct of space warfare. Just as limited wars were proliferated in response to the nuclear threat, counterspace warfare too will be conducted on a limited, non-destructive basis to coincide with terrestrial conflicts. This will in turn be countered by nations building robustness into their space architecture that takes advantage of newly available technology like carbon nanotubes and piezoelectrics. Like any other weapon, this too will be countered ultimately creating "trench warfare in the sky."

Space will remain in this state until a game-changing technology comes along that fundamentally alters its current purpose of providing effects on Earth. While space travel may ultimately serve this purpose, space-based energy production offers a more plausible technology leap that will have a profound effect on national security for the next century. While this technology may not be around for 50 years, it is certainly plausible that an unforeseen energy crisis may accelerate this timeline. This much is certain: mankind is a mere technology leap away from realizing a more permanent presence in space. Once this happens, the national security problem will evolve into an infinitely more complex challenge. From a quick survey of military theory, strategists have only begun to tackle the complexities of this emerging reality.

The United States need not sit on the sidelines as this unfolds. I offer three recommendations for our national leadership and military commanders to consider with respect to a more dynamic a use of space. First, establish "rules of the road" commensurate with the

forthcoming technology. Given that the OST was written in an age when nuclear war was of principle concern to the world, the OST should be revised to account for technologies and geopolitical realities of the 21st century. Second, the U.S. should seize the initiative in "staking claim" to territory in space and on the Moon. Technology trends over the next 30 years suggest that launch costs may go down by several orders of magnitude. This will in-turn increase demand to occupy strategic locations within the Earth-Moon system. Even if such a presence was established in a scientific capacity, the inherent ownership of such territory would go a long way when renegotiating the OST. Finally, the U.S. military should begin to consider how to fight more "jointly" in this ever-expanding landscape. Although some may be quick to advocate forming a separate space service, more critical is the recognition that space will behave more like a geographic combatant command than the functional command, as it is defined today. Very little theory has been written on the matter, but that must soon change if the U.S. is to remain on the leading edge of defense.

Despite the recent lull in activity, the future of space holds unique opportunities along with unprecedented risks. It is those nations who best prepare to meet the challenge that will reap its benefit.

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